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Digital development

Report of the Secretary-General

Executive summary

This report discusses digital development by analysing emerging changes in the digital development landscape with regard to digital technologies, digital demographics and development priorities. Special focus is given to television (TV) white space applications, next-generation satellites and the emergence of "millennials". The transformative impacts of these changes on our society are discussed. The report highlights the need to broaden the current discourse on information and communications technologies for development (ICT4D) and identifies four policy focus areas for facilitating effective digital development: the digital ecosystem, digital inclusion, digital sustainability and digital threats. Findings and policy suggestions in the context of the emerging post-2015 development agenda are provided.

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Introduction

1. The Commission on Science and Technology for Development at its seventeenth session, which took place in May 2014, chose "digital development" as one of the priority themes for its eighteenth session. It also decided that in addressing this theme, special attention should be given to millennials,[1] emerging technologies of white space applications and next-generation satellites.

2. To contribute to a better understanding of this theme and assist the Commission in its deliberations at its eighteenth session, the Commission secretariat convened a panel meeting in Geneva from 26–28 November 2014. This report is based on the findings of the panel, national briefings made by members of the Commission and other relevant literature.

3. Section I of the report describes the changing landscape of digital development in terms of emerging technologies, changing demographics and development priorities. Section II discusses the transformative impacts rendered by these changes in two sectors of the society, namely, the economy and politics. Section III discussing the implications of these changes for development and policymaking. Section IV highlights key findings and suggestions.

I. A changing digital development landscape

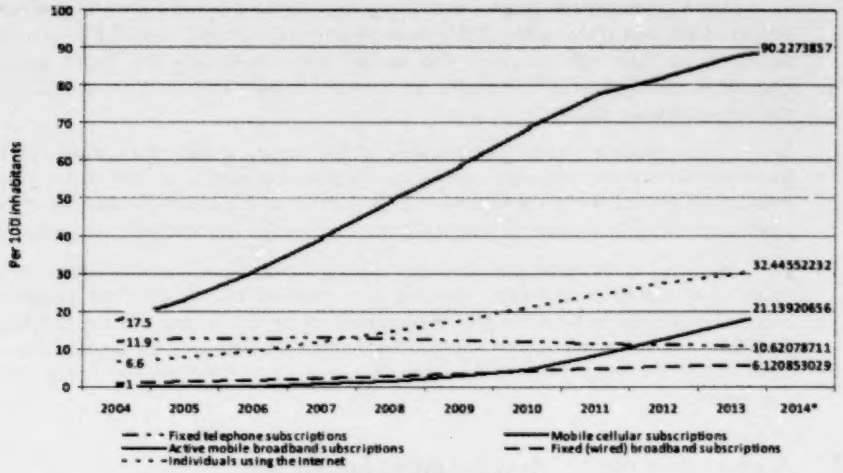
4. Since early 2000, the digital development landscape has changed in three significant, foundational areas: digital technologies, demographics and development priorities. This section examines these changes.

A. Changing digital technologies

5. Information and communications technology (ICT) has changed dramatically during the twenty-first century. Major ICT trends in developing countries are summarized in figure 1 below, which shows that mobile, broadband and mobile broadband (hence smartphones and tablets) will be a key driving force of future technology trends in ICTs. These figures smooth over many inequalities, which will be discussed later, but the overall change is clear: in 10 years, digital ICTs have moved from a peripheral role to a core role in our daily lives. Even in developing countries, they have increased their presence in terms of their reach, scope and depth. As a result, the existence of a digital "nervous system" for development is already beginning to appear: a pervasive digital infrastructure in which most development organizations, from international agencies to government departments and small community-based organizations, have Internet access and in which a large proportion of individuals in developing countries have digital mobile phone access.

[1] The term "millennials" refers to those who are born after 1980, the first generation to come of age in the new millennium.

Figure 1
Key information and communications technology indicators for developing countries, 2004–2014



Source: ITU World Telecommunication/ICT indicators database.

* Estimate

6. During its 2013–2014 intersessional period, the Commission highlighted five major emerging trends in digital technology: datafication, big data, cloud computing, the Internet of things, and smart systems (E/CN.16/2014/3). These trends are profoundly changing the digital development landscape. One of the observations made by the Commission was that harnessing their potential would require reliable, high-quality infrastructure. It is in this context that an analysis is made of two emerging technologies -TV white space and next-generation small satellites– that hold the potential to strengthen the ICT infrastructure, especially in developing countries.

Applications of television white space

7. Different radio frequencies are assigned or licensed by national and international regulatory bodies for specific purposes. The assignment of frequency bands leaves white space between allotted frequencies, which essentially forms a type of momentarily unused spectrum. Such unused spectrum is also the result of technical changes, such as the shift to digital television technology. Experiments and pilot projects are currently being carried out to use such white space for several applications, such as enabling broadband Internet connectivity, especially in rural areas.

Potential of white space applications

8. Especially in developing countries, one of the most widely experimented applications of white space technology has been to promote broadband Internet access to rural areas. Rural areas are often characterized by difficult terrain and are disconnected from the local power grid. White space power stations are set up to be charged with solar panels. Very high or ultra-high frequency[2] spectrum used in white space technology offers

[2] Commonly known by the acronyms VHF and UHF, respectively.

10 times the coverage of the traditional Wi-Fi spectrum with the same transmit power and promises higher penetration.[3] Hence, it is particularly suited to the difficult terrain that characterizes underserved rural areas; white space power stations are also set up to be charged with solar panels.

9. In addition to rural Wi-Fi, TV white space can also be effective during disaster response by creating an emergency broadband infrastructure. Further, when combined with effective automated devices, white space applications can be used to develop a system for environmental monitoring, including measuring pollution level, oil spills and intensity of climatic events, and issuing timely warnings. Other applications include border protection and monitoring of critical infrastructure such as power plants. They have the potential to facilitate a whole array of "smart city" applications and generate jobs directly and indirectly. By increasing the number of Internet service providers and people employed in the manufacturing of TV white-space-enabling instruments, new job opportunities are created. At the same time, the availability of broadband Internet in previously unserved areas could result in new establishments and business models that generate jobs indirectly. Several pilot projects related to TV white space applications are currently under way in several developing countries.[4] Most of them have been successful in connecting local schools, universities and similar public infrastructure, as well as providing broadband Internet connectivity to previously unserved rural communities.

Next-generation small satellites

10. Another emerging telecommunication technology is that of next-generation small satellites, such as nanosatellites and picosatellites, which are relatively fast to develop, and inexpensive to build and launch. These satellites weigh from 1–10 kg, have an edge length of less than 30 cm and a typical mission lifespan of less than three years.[5]

Potential of small satellites

11. These small satellites are bringing space into everyday life. They offer greater individualized satellite access for entertainment and education, and a myriad of practical applications such as weather forecasting, earth observation, climate change adaptation and mitigation, forest fire detection and monitoring, remote sensing and communication.[6] Advancements in electronics and instrumentation have increased the capabilities of smaller satellites, making them increasingly comparable to that of their larger and more expensive counterparts.

12. Small satellites open up an easy access route to space to a large number of developing countries. By engaging in small satellite development and deployment developing countries can build their technological capabilities related to space technology. These capabilities can in turn be used to develop and adapt satellite technology applications to deal effectively with specific local problems related to issues such as rural connectivity,

[3] A Mody, 2014, presentation made at the 2014–2015 Intersessional Panel meeting of the Commission on Science and Technology for Development, held in Geneva in November.

[4] For details on white space pilot trials, see http://research.microsoft.com/en-us/projects/spectrum/pilots.aspx, accessed 18 February 2015.

[5] M Buscher and K Briess, 2014, Analysis of Regulatory Challenges for Small Satellite Developers Based on the TUB Small Satellite Database, presentation given at the International Telecommunication Union (ITU) workshop on the efficient use of the spectrum/orbit resource, Limassol, Cyprus, 14–16 April.

[6] P Platzer, 2013, Nanosatellites will give everyone access to space, Techonomy, 8 November, available at http://techonomy.com/2013/11/nanosatellites-will-give-everyone-access-space/, accessed 18 February 2015.

deforestation monitoring, crisis management and famine detection. Many university students, including undergraduate students from developing countries, are currently engaged in developing these microsatellites. Also, several private sector firms are launching microsatellites with specific commercial applications.

13. These emerging digital technologies require an enabling environment for their wide-scale adoption. An enabling environment includes, inter alia, appropriate licensing mechanisms to conduct pilot projects, clarity in terms of regulations and awareness about the potential of these technologies. The first step in this direction would be to ensure that these new technologies do not create interference with established technologies. For instance, the usage of TV white space should not interfere with the primary usage of TV spectrums for transmitting television channels. Likewise, small satellites should be deployed and used in such a way that they do not create an obstruction to existing satellite infrastructure or violate international regulations governing them.[7] This would entail policy and regulatory intervention by governments and relevant international organizations. Inertia from regulators can hinder the adoption and promotion of these technologies.

14. Thanks to these advances in telecommunications, the blank spaces on the digital map are gradually being erased, and there is a transition towards being connected everywhere at all times. There is a still a long way to go, but within a generation almost everyone will be connected, and it is likely that full connectivity will gradually become a reality.

B. Changing digital demographics

15. The technology changes outlined above have been accompanied with changes in demographics of ICT usage. The geographic composition of Internet users has changed, indicating significant progress in the bridging of the global digital divide in terms of access.[8] Geographically, in terms of number of users, the "new Internet world" (emerging nations of the global East and South) have already surpassed the "old Internet world" (the United States and Europe).[9] There are now twice as many Chinese citizens online as there are United States citizens in total; the Middle East and Africa have more users than Western Europe.[10] Some argue that ICTs are more central to the lives of these new Internet world users and that the latter are more sociable online, produce more online content and source more of their audio-visual content online.[11]

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[7] Y Henri, 2014, Current Satellite Regulatory Issues, and T Azzarelli, 2014, International Regulations for Nano/Pico Satellites, presentations given at the ITU workshop on the efficient use of the spectrum/orbit resource, Limassol, Cyprus, 14–16 April.

[8] G Bolsover, W H Dutton, G Law and A Dutta, 2014, China and the US [United States of America] in the new Internet world: A comparative perspective, in *Society and the Internet: How Networks of Information and Communication are Changing Our Lives*, M Graham and W H Dutton, eds, Oxford University Press, Oxford, United Kingdom of Great Britain and Northern Ireland, 117–134.

[9] Ibid.

[10] Internet Live Stats, 2014, Internet Users by Country (2014), available at http://www.internetlivestats.com/internet-users-by-country/, accessed 18 February 2015; Internet World Stats, 2014, Usage and Population Statistics, available at http://www.internetworldstats.com/stats.htm, accessed 18 February 2015.

[11] Bolsover et al., 2014, op. cit.

Emergence of millennials or digital natives

16. A large share of the newer Internet users is represented by the "growing up digital" generation.[12] "Digital natives" can be defined as those 15–24 year olds with five or more years of online experience.[13] They are more likely than others to consume and produce online content, and perceive themselves as being more innovative and creative; what is more, ICTs are changing the way they think and learn.[14] While only around one fifth of the youth cohort in developing countries are digital natives, compared with four fifths in the global North, youth in the global South are twice as likely to be digital natives as the total population, so they have a disproportionate role that might be worth specific encouragement.[15]

17. As mentioned previously, the term "millennials" refers to a larger age cohort of those who are born after 1980, essentially the first generation to come of age in the new millennium.[16] This is the generation to follow Generation X, and according to recent estimates, would comprise 75 per cent of the global work force by 2025.[17] A distinguishing feature of this generation is that they are the first growing up digital generation. The bulk of their activity, including peer-to-peer communication and knowledge management, is mediated by digital technologies.[18] Given that they make proportionately greater use of digital technologies and social networks than other categories, the engagement of these digital natives – for example in education or politics – may be enhanced by ensuring effective digital channels in these sectors. ICT opens up innovative ways to deliver education to the younger generation. Further, ICT has a major role to play in facilitating collaboration and partnerships between the millennials of the global North and South, and among the millennials within these regions as they seek effective solutions to developmental problems.

18. Yet access to ICT alone does not guarantee reaping its full benefits. It is necessary to climb up the digital "role ladder",[19] that is to say, to make the transition from being active users of e-mail and Internet applications to becoming producers, entrepreneurs and innovators, taking advantage of ICT-enabled opportunities. Climbing up this ladder would

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[12] D Tapscott, 1998, *Growing Up Digital: The Rise of the Net Generation*, McGraw-Hill, New York, United States.

[13] ITU, 2013, *Measuring the Information Society 2013*, ITU, Geneva, available at http://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2013.aspx, accessed 18 February 2015.

[14] J Lehrer, 2010, Our cluttered minds, *The New York Times*, 3 June, available at http://www.nytimes.com/2010/06/06/books/review/Lehrer-t.html, accessed 18 February 2015; G Blank and W H Dutton, 2014, Next Generation Internet Users: A New Digital Divide, in *Society and the Internet: How Networks of Information and Communication are Changing Our Lives*, M Graham and W H Dutton, eds, Oxford University Press, Oxford, United Kingdom, 36–52; *The Economist*, 2014, Briefing: The staid young, 12 July.

[15] ITU, 2013, op. cit.

[16] Pew Research Center, 2010, Millenials: A Portrait of Generation Next, February, available at http://www.pewresearch.org/millennials/, accessed 19 February 2015.

[17] Deloitte, 2014, *The Deloitte Millenial Survey 2014: Big Demands and High Expectations*.

[18] Francesc Pedró, 2006, The new millennium learners: Challenging our views on ICT and learning, Centre for Educational Research and Innovation, Organization for Economic Cooperation and Development (OECD), available at http://www.oecd.org/edu/ceri/38358359.pdf, accessed 19 February 2015.

[19] R Heeks, 2014, *ICTs and Poverty Eradication: Comparing Economic, Livelihoods and Capabilities Models*, Development Informatics Working Paper No. 58, Institute for Development Policy and Management (IDPM), University of Manchester, United Kingdom, available at http://www.seed.manchester.ac.uk/subjects/idpm/research/publications/wp/di/, accessed 19 February 2015.

require the development of capabilities – technological and other skills such as critical and analytical thinking, problem solving and creativity. Although there is a surge in the number of millennials from developing countries who are active Internet users, very few end up climbing up the role ladder to become producers, entrepreneurs or innovators, as they lack the necessary digital capabilities and enabling opportunities. This highlights the urgent need for a capabilities-based approach to ICT capacity-building, especially in developing countries.

C. Changing development priorities

19. The current ICT4D discourse, including the two World Summits on the Information Society in 2003 and 2005, were significantly shaped by the Millennium Development Goals. This approach focused largely on mitigating social deprivation. The Declaration of Principles[20] adopted in Geneva at the World Summit on the Information Society in 2003 proclaimed that "our challenge is to harness the potential of ICT to promote the development goals of the Millennium Declaration" and recognized ICTs as "tools" to achieve development goals. These development priorities that shaped the current ICT4D discussion have also evolved since the early 2000s. The Rio+20 Conference of 2012 called for a set of sustainable development goals that encompasses three dimensions of sustainable development: economic, social and environmental. These goals will be part of a post-2015 development agenda envisaged to be strong, ambitious, inclusive and people centred.[21] Three core themes in development can be identified from the emerging post-2015 development agenda discussions:[22]

(a) Transformation: It is clear that "business as usual" would not deliver on the ambitious post-2015 development agenda. There has been a call for a paradigm shift in the development approach that is truly transformative;[23]

(b) Inclusion: The development process should ensure equal opportunities – that all people, regardless of their background, can achieve their full potential in life. Such efforts include policies and actions that promote equal access to public services and enable citizens' participation in the decision-making processes that affect their lives;[24]

(c) Sustainability: "[d]evelopment that meets the needs of the present without compromising the ability of future generations to meet their own needs".[25]

20. The subsequent sections of this report show the intricate linkages between ICT and the three core themes of the post-2015 development agenda. Further, ICT also plays a

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[20] WSIS-03/GENEVA/DOC/4-E.

[21] E/2014/L.22–E/HLPF/2014/L.3.

[22] R Heeks, 2014, *From the MDGs to the post-2015 agenda: Analysing changing development priorities*, Development Informatics Working Paper No. 56, IDPM, University of Manchester, United Kingdom, available at: http://www.seed.manchester.ac.uk/medialibrary/IDPM/working_papers/di/di_wp56.pdf, accessed 19 February 2015.

[23] One year on: An open letter from former members of the UN [United Nations] Secretary-General's High-Level Panel of Eminent Persons on the Post-2015 Agenda, 22 September 2014, available at http://www.un.org/sg/management/pdf/HLP_2015_open_letter_sept_2014.pdf, accessed 19 February 2015.

[24] Working definition of social inclusion from the Department of Economic and Social Affairs; see http://undesadspd.org/socialintegration/definition.aspx, accessed 19 February 2015.

[25] World Commission on Environment and Development, 1987, *Our Common Future*, Oxford University Press, Oxford, United Kingdom.

crucial role in shaping the development agenda by providing space and opportunity for wider consultations. During the conception of the Millennium Development Goals, the international community was only beginning to understand the "catalytic potential of ICTs to advance development agendas and priorities". Further, it is necessary to recognize ICT as "cross-cutting enablers for the achievement of all three pillars of sustainable development".[26] Hence, taking into account these changing development priorities, it is clear there is a need to re-evaluate the role of ICT in development.

II. Transformative impacts on society

21. Emerging changes in the digital development landscape, discussed in the first part of the report, are already creating transformative impacts on many facets of our society. This section discusses some of the key transformative impacts of these changes on two important sectors of society, namely, the economy and politics.

A. Digital economy

22. There are attempts to measure the size of the ICT sector or the Internet economy.[27] These estimates indicate that these elements of the digital economy typically represent less than 10 per cent of gross domestic product, even in the more developed economies. These sectors are growing faster than the general economy but the majority of ICT gains are captured by the traditional economy. By looking at the changes associated with ICTs in the economic sphere, two types of change can be identified: incremental transformations that take existing models and improve their coverage or performance, and disruptive transformations that truly harness the power of ICTs to create fundamentally new business models. Each of these will be described in turn.

Incremental transformation

23. A key problem of the poor in developing countries is that they can be excluded from economic opportunities by lack of access to information. ICTs can help overcome such barriers. As well as improving economic opportunities for marginalized groups, ICTs can improve the functioning of existing businesses. They can cut operational costs and expand market reach for all scales of firms, helping them improve their sustainability and profitability. Further, ICTs enable consumers to be part of the production process. For example, a survey among millennials in South Africa revealed that 74 per cent are

[26] Joint Statement of the United Nations Group on the Information Society on the Post-2015 Development Agenda, Geneva, 2013.

[27] OECD, 2008, *The Seoul Declaration for the Future of the Internet Economy*, OECD, Paris, available at http://www.oecd.org/internet/consumerpolicy/40839436.pdf, accessed 19 February 2015. See also McKinsey and Company, 2011, *Internet Matters: The Net's Sweeping Impact on Growth, Jobs, and Prosperity*, McKinsey Global Institute, available at http://www.mckinsey.com/features/sizing_the_internet_economy, accessed 19 February 2015; Boston Consulting Group, 2012, *The Internet Economy in the G-20: The $4.2 Trillion Growth Opportunity*, Boston Consulting Group, Boston, Massachusetts, available at https://www.bcg.com/documents/file100409.pdf, accessed 19 February 2015; OECD, 2013, *Measuring the Internet Economy*, Paris, available at http://dx.doi.org/10.1787/5k43gjg6r8jf-en, accessed 19 February 2015; European Commission, 2014, Digital Economy – Facts and Figures, Expert Group on Taxation of the Digital Economy, European Commission, Brussels, available at http://ec.europa.eu/taxation_customs/resources/documents/taxation/gen_info/good_governance_matters/digital/2014-03-13_fact_figures.pdf, accessed 19 February 2015.

connected with various companies and brands online, and they expect their feedback on various products to be reflected in future product design.[28] ICTs can even change the performance of groups of businesses. Small and medium-sized enterprises have often struggled to grow, but ICTs enable such networks to work together at relatively low cost. This can allow such enterprises in low-income locations to compete, when otherwise they might be driven out of business by large firms.

Disruptive transformation

24. Digital technologies can go beyond incremental transformation and create much greater change that may challenge existing ways of doing business. ICT has facilitated the creation of digitally enabled products through the creation of new digital products and the digitization of existing products. Examples include the conversion of books into e-books, newspapers into news websites and classroom education into e-learning. Similarly, ICT applications in businesses have led to new digital business models. Most digital business models are traditional ways of doing things but with the overlayering of ICT. They come with distinguishing features such as being virtual, open, crowd sourced and shared. One such business model is that of highly profitable information monopolies, where, significant power and control is vested in large ICT firms, compared with their consumers and nation States. At the same time, in some countries, popular ICT applications make certain services, such as hospitality and transportation, more competitive and disrupt the current market dynamics in these sectors. ICT applications have also facilitated cooperative, community-based economic models that can be equally disruptive, as they challenge mainstream ways of doing business. For example, open-source models such as open-source software production are based on a commitment to sharing and open participation among a community of peers. They are only feasible because of the sharing and coordination made possible by ICTs.

B. Digital politics

25. Similarly to the economic realm, the transformative impacts of ICTs on politics can be broken down into the incremental and the disruptive. These transformations in the political realm are facilitated by the strengthening of all types of networks by ICT applications. These networks, which include people, devices and organizations, are fast becoming increasingly complex. Also, these network structures will have less of a physical, and more of a virtual, existence. Millennials and digital natives are playing key roles in these networks and as a result are instrumental in ushering in political changes, as they use ICT as a platform for engaging in public life.

Incremental transformation

26. Many people in developing countries are excluded from fair access to public services. ICTs can help overcome some of these issues by reaching out to low-income communities though e-government and m-government applications. Evidence suggests this can make public services quicker and cheaper to access, for example, by eliminating the need to travel to district headquarters; improve consistency and citizen satisfaction; and significantly reduce corruption. ICTs can also be used to improve government in other ways. Particularly, they can help the voice of the people to be heard in ways they previously were not. With regard to ICT-enabled political campaigns – which may involve

[28] M Mbugua, 2014, Zooming in on the South African millennial, August, available at: http://www.whyweare.co.za/article/millennials, accessed 19 February 2015.

e-petitions but also a broader range of online communication – governments have been pushed to change their legislative programmes and hold politicians more accountable.

Disruptive transformations

27. Digitally enabled social movements give voice to alternative politics. At times, these new social movements have been credited with enacting regime changes.[29] Although the precise role of ICTs in many of the revolutionary movements is debatable, there is general acceptance that some regime changes would not have taken place or at least not in the same manner or timescale, had it not been for ICTs. Similarly, new digital models that empower citizens to a much higher degree are being witnessed. Examples include initiatives such as:

(a) E-accountability: Electronic accountability systems seek to solve problems of corruption or underperformance in government. Online applications are being used by citizens to track performance against politicians' promises, report corruption of public officials, track budget payments to their intended destinations and show which officials handled a licence application;

(b) E-participation: This type of initiative helps people participate in government decisions. Citizens are often highly motivated to engage with such initiatives, and it can change their view of themselves and their governments;

(c) E-collaboration: Citizens can co-produce government goods and services by using ICTs. For example, interactive community mapping has been undertaken in Africa, using community members and others to capture details of roads, buildings and facilities on a digital map.

28. At the opposite end of the spectrum, some digital applications significantly shift power towards governments. For example, some States make use of e-surveillance to gather evidence that is used to repress their opponents. They also actively use ICTs for repressive purposes. As the activities and lives of citizens are increasingly played out online, digital technologies could also allow greater government monitoring and control over citizens.

III. Policy implications of a changing digital development landscape

A. Broadening the ICT for development discourse

29. The ICT4D discourse emerged in the mid-1990s and saw digital ICTs as a useful tool for development. The paradigm arose because of the rough coincidence between general availability of the Internet – a tool in search of purposes – and the Millennium Development Goals – purposes in search of tools. Following the launch of the Goals, ICTs began to be integrated more into development plans and projects as a tool to deliver development. From the development side, this is expressed in national policy portfolios, poverty reduction strategy papers and the United Nations Development Assistance Frameworks. From the ICT side, this is expressed in national ICT policies and action lines of the World Summit on the Information Society.

[29] R Heeks and R Seo-Zindy, 2013, ICTs and social movements under authoritarian regimes: An actor-network perspective, Development Informatics Working Paper No. 51, IDPM, University of Manchester, United Kingdom , available at http://www.seed.manchester.ac.uk/subjects/idpm/research/publications/wp/di/di-wp51/, accessed 19 February 2015.

30. Over the years, the ICT4D discourse has focused on the incremental impacts of technology, such as improvements in the efficiency of microenterprises and better delivery of health or market information. However, this does not encompass the broader, disruptive transformations that ICT is increasingly enabling in our society, as discussed in the previous section. ICT is becoming part of a digital nervous system that fast underpins almost all development activities. As a result, some of the limitations of the initial ICT4D perspective are becoming evident, with clear implications for policymaking. For example, a key policy focus of the ICT4D approach has been the digital divide, with considerable emphasis on those who are not digitally connected. However, it has become increasingly evident that simply focusing on access misses the point. As more areas and people become digitally connected, new divides are emerging in terms of capabilities and resources. Further, the original ICT4D perspective has taken a limited view of ICTs within development policy, seeing them as an assistive add-on to some aspects of that policy. But this view will be out of sync with a world in which ICTs are becoming a pervasive foundation for all aspects of development policy. And, structurally, the initial ICT4D perspective fragments policy responsibilities into silos of many individual development sectors such as health, education and rural development, when coherent policy linking those silos would be necessary.

31. Hence there is an increasing need to broaden the ICT4D discourse so as to incorporate these changing realities into the digital development landscape. The ICT4D discourse should recognize ICT as a platform that increasingly mediates development. In other words, digital technologies need to move from a peripheral role in development to being a central means by which to achieve and experience development.

B. Policy focus areas of digital development

32. To accommodate the changing digital development landscape, it is necessary to expand the ICT4D discourse. This would imply policy interventions in four key areas: the digital ecosystem, digital inclusion, digital sustainability and digital threats. Each of these four policy focus areas will be explored below, with some suggestions for policy interventions.

Digital ecosystem

33. The digital ecosystem can be understood as the space formed by the convergence of the media, telecommunication and information technology industries.[30] Such an ecosystem involves components such as technological infrastructure, data infrastructure, financial infrastructure, institutional infrastructure and human infrastructure. The digital ecosystem provides the inputs necessary to create the technical foundations, and social and technical applications required for effective digital development.[31] The private sector may not invest adequately in all components of digital ecosystems, as ecosystem investments are a type of public goods characterized by the inability of the investor to capture all the returns on investment. Policy intervention is therefore required to set up an efficient digital ecosystem.

[30] World Economic Forum, 2007, *Digital Ecosystem Convergence between IT, Telecoms, Media and Entertainment: Scenarios to 2015*, Geneva, available at http://www3.weforum.org/docs/WEF_DigitalEcosystem_Scenario2015_ExecutiveSummary_2010.pdf, accessed 19 February 2015.

[31] R Heeks, 2014, *ICT4D 2016: New Priorities for ICT4D Policy, Practice and WSIS in a Post-2015 World*, Development Informatics Working Paper No. 59, IDPM, University of Manchester, United Kingdom, available at http://www.seed.manchester.ac.uk/subjects/idpm/research/publications/wp/di/, accessed 19 February 2015.

However, such public intervention should not merely aim to increase public investment, but rather aim to create incentives for private sector investment and ensure their involvement, wherever possible. The dynamism, power and resource access of the private sector needs to be harnessed and should be a driving force for digital development.

34. A first step towards strengthening any national digital ecosystem would include an audit of the current digital ecosystem to identify particular areas of weakness. Policy interventions should orient multiple channels of finances towards strengthening the weaker components of the digital ecosystem. One of the key objectives of State policy should be to ensure a pervasive high-capacity, interoperable technological and data infrastructure. This would involve policy interventions by enabling regulatory policies, making direct investments, building public–private partnerships and setting quality standards. This should be accompanied by a supportive legal and institutional infrastructure that promotes digital innovation capabilities at ground level.

35. Most importantly, the human infrastructure needs to be strengthened in terms of ICT production and consumption capabilities, including complementary capabilities such as communication, and interpersonal and analytical skills. These complementary capabilities are essential in converting ICT skills to productive employment opportunities. This calls for educational policy interventions at primary, secondary and tertiary educational and vocational training levels. Focus should also be on how to empower people to emerge as innovators and producers of ICT applications suited for specific local needs.

Digital inclusion

36. ICT can empower people. At the same time, however, lack of digital access and inadequate digital capabilities can exacerbate inequalities in society. Digital development is based on networks. In this context, three groups can be clearly distinguished: "the haves", who have access to all required resources and skills; the "have-nots", who are completely cut off from any direct benefits of ICTs; and the "have-lesses", who are often prevented from deriving maximum benefits from digital development.[32] Most of the millennials of the global South can be classified as digital have-lesses. For example, the millennials in several African countries, though exposed to opportunities offered through various online hosting platforms, find it increasingly difficult to make use of them because their domestic banking system has not yet been integrated into global payment gateways.[33] Also, digital inequality tends to reflect the existence of other inequalities in society in terms of employment, education and income, based on subgroups such as gender[34] and ethnicity. These inequalities can be worsened by the lack of appropriate local content in ICT applications.

37. In this context the linkage between ICT and gender inequality merits special attention. Women are 23 per cent less likely to use the Internet in low-to-medium income countries, while in sub-Saharan Africa, this gap widens to 43 per cent.[35] This access divide

[32] M Castells, 2010, *The Information Age: Economy, Society, and Culture*, second edition, Wiley-Blackwell, Chichester, United Kingdom.

[33] V Counted, 2014, We are connected, but constrained: Internet inequality and the challenges of millennials in Africa as actors in innovation, Third Millennium Africa Project, conference paper: second International Conference on Innovation and Entrepreneurship, University of Bangkok, Thailand.

[34] M Hilbert, 2011, Digital gender divide or technologically empowered women in developing countries? A typical case of lies, damned lies, and statistics, *Women's Studies International Forum*, 34 (6), 479–489, November-December, available at http://dx.doi.org/10.1016/j.wsif.2011.07.001, accessed 19 February 2015.

[35] Intel, Dalberg Global Development Advisors and Globescan, 2012, *Women and the Web: Bridging the Internet Gap and Creating New Global Opportunities in Low and Middle-income Countries*,

can exacerbate the existing gender inequality of development outcomes and leave women further behind. At the same time, ICT could be a game changer in terms of empowering women, if supported by adequate policy interventions to overcome gender-specific barriers. Therefore, attaining gender parity with regard to digital access and digital capabilities should be a special focus of ICT policies, especially in developing countries.

38. Inclusive digital development does not merely imply providing access to ICT; it also implies improving access to complementary resources and obtaining capabilities that enable digital access to be turned into development results. The full digital ecosystem should be extended to encompass excluded groups of society. It is important that the digital ecosystem audit proposed earlier should also identify dimensions of digital exclusion, as well as the key constraints faced by such excluded groups. Policy interventions should aim to create incentives to promote inclusive digital innovations. ICT capability building of marginalized groups should be a top priority. Community-based capacity-building initiatives tailored to local needs could help in this regard. Policy interventions must also incentivize local ICT innovation and development capacities within developing countries that can create inclusive data, local content and inclusive applications.

Digital sustainability

39. The linkages between ICTs and sustainability can be understood in terms of the level or order of the impacts.[36] The physical existence of ICT sectors have direct impacts on sustainability, but through numerous applications in non-ICT sectors, ICT can substantially contribute towards improving sustainability in an indirect manner. The reduction in carbon emissions due to smart grids and the automation of the power sector can be considered indirect applications. In addition, ICT also creates behavioural and societal changes. Their aggregate impacts will have transformative impacts on sustainability that are relevant not only to the environment, but also to economic prosperity and social equity. For example, changes in consumption patterns triggered by ICT usage have vast sustainability implications. Further, ICT also has the potential to help improve the resilience of systems. There is therefore a need for a holistic approach that takes on board all these multiple linkages of ICT and sustainability, while planning policy interventions.

40. In terms of policy interventions, encouraging sustainability initiatives within ICT sectors and ensuring adequate recycle and disposal facilities for e-wastes can help reduce considerably the direct environmental impacts of ICT. The indirect positive impacts of ICT can only be realized through capacity-building measures and creating an enabling environment for smart applications in non-ICT sectors. Governments should also encourage research on the behavioural and aggregate impacts of ICT on society and the resultant sustainability implications. Applications of ICT to improve resilience of development subsystems need to be facilitated.

Santa Clara, California, United States, Intel Corporation, available at http://www.intel.com/content/dam/www/public/us/en/documents/pdf/women-and-the-web.pdf, accessed 19 February 2015.

[36] This framework was proposed by the European Union Forum for the Future in 2002 and is further explained in D Souter and D MacLean, 2012, *Changing our Understanding of Sustainability: The Impact of ICTs and the Internet*, International Institute for Sustainable Development, December, 2012, available at http://www.iisd.org/sites/default/files/pdf/2012/changing_our_understanding_of_sustainability.pdf, accessed 19 February 2015.

Digital threats

41. Digital development outcomes vary from jurisdiction to jurisdiction in terms of their legality but that are regarded in many contexts as problematic and as potential threats to society. It has been found that cybercrime incurs economic, political and social costs. The extent of problems caused by gambling[37] and pornography is exacerbated online. ICT sometimes becomes a platform to perpetrate violence against women and girls. Further, the intersection between human rights and the digital world has given rise to several instances of human rights curtailment. While there are some benefits attached to ICT-related monopolies, they also pose challenges such as raising barriers to entry, predatory pricing, invasions of privacy and tax avoidance.[38]

42. Policy measures to fight cybercrime would involve strengthening cybersecurity agencies and spreading awareness of cybercrime. Appropriate legislation should be adopted to ensure that universal human rights are respected online as much as offline. The threats associated with online pornography and gambling also call for effective policy interventions, which may involve appropriate legal measures suited for different national contexts. It is important to develop mechanisms to combat the use of ICT and social media to perpetrate violence against women and girls, including the criminal misuse of ICT for sexual harassment, sexual exploitation, child pornography and trafficking in women and girls, and emerging forms of violence such as cyberstalking, cyberbullying and privacy violations that compromise the safety of women and girls.[39] Greater support for "open development" activities[40] could potentially challenge the monopolistic and proprietary models of ICT activities.

C. Digital development policy governance

43. To encourage effective digital development, more than new policy content is necessary. Policymakers must also consider the governance of digital development policy, especially the structures through which digital development policy is made. During the pre-digital era, the structural approach to ICT policy has been sidestreaming, that is to say, locating ICT policy in a single specialist body, generally a government ministry with one or more of the following in its title: "information", "communications" and "technology".

44. The ICT4D perspective aims to encourage countries to mainstream ICT policies, that is to say, to shift or develop responsibilities for ICT-related policy within other

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[37] RJ Williams, RT Wood and J Parke, 2012, History, current worldwide situation, and concerns with Internet gambling, in *Routledge International Handbook of Internet Gambling*, RJ Williams, RT Wood and J Parke, eds, Routledge, Abingdon, United Kingdom, 3–26.

[38] DS Evans, 2008, Antitrust issues raised by the emerging global Internet economy, *Northwestern University Law Review Colloquy*, 102:285–306, available at http://www.law.northwestern.edu/journals/lawreview/Colloquy/2008/13/LRColl2008n13Evans.pdf, accessed 19 February 2015; KL Levine, 2008, Preserving competition in multi-sided innovative markets, *North Carolina Journal of Law and Technology*, 10(1), 59–117, available at http://www.ncjolt.org/sites/default/files/Devine_Kristine_v10i1_59_118.pdf, accessed 19 February 2015.

[39] United Nations, The elimination and prevention of all forms of violence against women and girls: Agreed conclusions, Commission on the Status of Women, Fifty-seventh session, 4–15 March 2013, available at http://www.un.org/womenwatch/daw/csw/csw57/CSW57_agreed_conclusions_advance_unedited_version_18_March_2013.pdf, accessed 19 February 2015.

[40] ML Smith, L Elder and H Emdon, 2011, Open development: A new theory for ICT4D, *Information Technologies and International Development*, 7(1), iii-ix.

ministries. The need for mainstreaming becomes even greater as countries continue to give ICTs a more central role in their development policies. Hence, every ministry would be involved in policy for digital development, which encourages pervasive mainstreaming of ICT policy in the future. However, there are several problems with mainstreaming.[41] These include a lack of adequate understanding of ICTs within mainstream ministries, and fragmentation and incoherence of digital policy across sectors. Therefore, following up on the aforementioned digital-ecosystem approach, it becomes clear that a holistic understanding and allocation of responsibilities is necessary, as shown below.

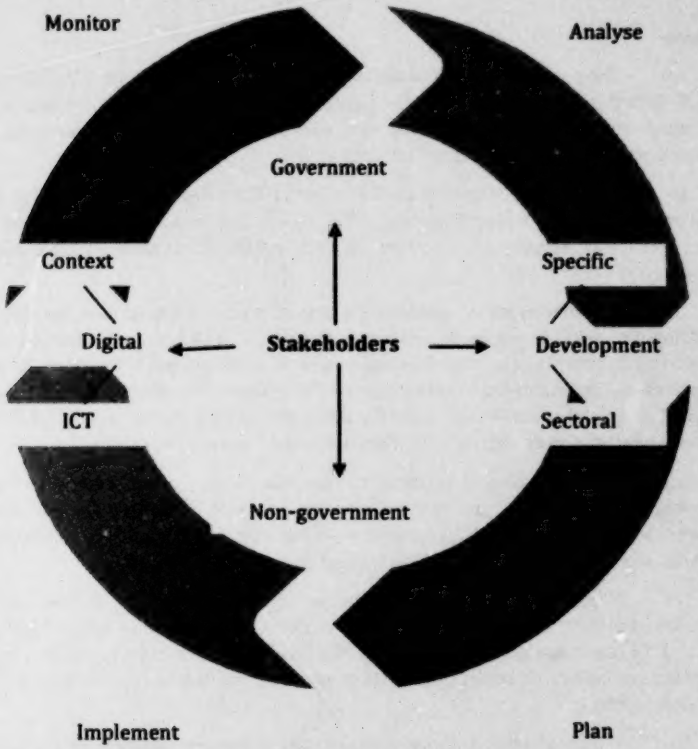
Digital development policy responsibilities

Policy actors	*Policy responsibilities*
Core ICT policy (e.g. ministry of ICT)	Technical and data elements of digital ecosystem, inclusion, sustainability, threats policies
Contextual policy (e.g. ministries of finance, enterprise, trade and industry, education, science and technology)	Broader aspects of digital ecosystem and digital inclusion policies: finance, capabilities, digital processes, business development, innovation
Specific policy	Particular aspects of particular policies, e.g. digital inclusion (ministry of community development); digital sustainability (ministry of environment); digital threats (ministry of information and media; ministry of trade and industry)
Sectoral policy (e.g. ministries of agriculture, health, education, finance, enterprise, public administration, national security)	Sectoral aspects of digital ecosystem policy promoting transformative ICT application
International policy (e.g. United Nations and other supranational bodies)	Cross-national aspects of digital ecosystem, inclusion, sustainability, digital threat policies
Business strategy (e.g. leading, transnational digital corporations)	Recognition that business strategies of key digital corporations form part of the policy system
Civil society	Informing the government about the needs of society, weak links in the digital ecosystem, specific issues related to digital inclusivity, sustainability and managing digital threats.

45. To ensure the effective allocation of responsibilities, a cross-cutting collaborative structure may need to be created. As shown in figure 2, this structure will perform a dual bridging role, horizontally drawing in policy actors from both ICT and development; and vertically, those connected with government and other sectors. Indeed, experiences with various types of ICT policy suggest the value and merits of autonomous and capable State agencies, combined with strong representative bodies for both the private sector and civil society, and a mechanism for robust interaction between these three groups.

[41] R Heeks, 2010, Mainstreaming ICTs in development, *ICT4DBlog*, 30 October, available at http://ict4dblog.wordpress.com/2010/10/30/mainstreaming-icts-in-development-the-case-against/, accessed 19 February 2015.

Figure 2
Collaborative structure for digital development policy



46. Governments may seek to develop a single collaborative structure for all areas of digital development policy. However, this could become unwieldy, given that digital activity extends to every area of government responsibility. It may be advisable to consider structures along the main policy focus areas, such as the digital ecosystem, inclusion, sustainability and threats. Special attention should be given to convergence issues, in order to ensure coherence in policy. For example, ministries of finance and ICT will need to work together on the implications of m-money and e-money becoming the basis for financial and banking transactions; ministries of employment and ICT will need to work together on the implications of how best to generate jobs for the millennials and digital natives, and to identify in advance sectors that will lose jobs due to ICT applications in the future. Further, ministries of education and ICT will need to work together on the increasing digital mediation of learning.

47. It is important to adopt an experimental and iterative approach to digital development policy, allowing incremental learning and policy revision. The Commission should continue to provide a forum for the sharing of good practice experiences and lessons learned in digital development policymaking.

IV. Findings and suggestions

48. This section summarizes the findings presented above and proposes a set of key issues for consideration by the Commission on Science and Technology for Development.

Findings

(a) The potential of ICTs as cross-cutting enablers of sustainable development is not well embedded in the post-2015 development agenda discussions. References to ICTs are limited and inadequate within the outcome documents of Rio+20 and the Open Working Group on Sustainable Development Goals;

(b) There is a need to broaden the current ICT4D discourse to give ICTs a more central role in the development process. ICTs should not be seen merely as tools that achieve particular aspects of development, but rather as a platform that mediates development;

(c) TV white space or momentarily unused spectrum applications have potential in bridging the digital divide by ensuring broadband rural Wi-Fi access in many countries. They also could contribute to generating jobs in areas such as disaster response, smart city applications and environmental monitoring. While regulatory measures are currently being developed in several countries to enable the development of TV white space applications, regulatory inertia in many countries impedes wider application of this technology;

(d) Next-generation small satellites provide an easy access route to space for developing countries, as they are easy to build and relatively inexpensive. These satellites have applications in areas such as agriculture monitoring, climate change mitigation and adaptation, disaster response, weather monitoring and rescue operations;

(e) While the ICT access divide has been narrowing with the increased penetration of mobile technology, the divide in terms of capabilities has been widening. As a result, ICTs can create and also exacerbate the inequalities that exist in society. Further, inadequate availability of appropriate local content on the Internet can hinder inclusive digital development;

(f) A well-developed digital ecosystem is a primary requirement for effective digital development and the facilitation of transformative impacts in society through ICTs. Recognizing and reinforcing the linkages between different components of the digital ecosystem and strengthening its weaker components is crucial;

(g) ICTs are an essential means to unleash and channel the potential of millennials and digital natives towards sustainable development processes. Although the majority of millennials in developing countries use ICT applications, they lack digital innovation capabilities to emerge as entrepreneurs and producers using ICTs;

(h) While ICTs have some direct negative impacts on environmental sustainability through the creation of e-wastes, they also have the potential to promote environmental sustainability indirectly through their application in other sectors and by improving the resilience of the entire ecosystem;

(i) The increased use of ICTs facilitates risks associated with digital threats such as the curtailment of human rights, cybercrimes, gambling, pornography and the creation of monopolies. Millennials are particularly vulnerable to such threats;

(j) The cross-cutting nature of digital policies calls for the creation of collaborative structures for digital policy that involve all relevant stakeholders in order to ensure policy coherence and effectiveness.

Suggestions

49. The Commission is encouraged to take the following steps:

(a) Inform the post-2015 development agenda process on the need for a more central role of ICTs as an enabler and means of achieving the sustainable development goals, through substantive inputs to relevant processes and bodies within the United Nations;

(b) Provide a forum for sharing best practices in terms of developing national and regional regulations and incentive mechanisms to facilitate the application of new emerging technologies such as TV white space applications and next-generation small satellites, in bridging the digital divide and promoting sustainability;

(c) Act as a repository of best practices in policy measures to enhance digital innovation capabilities, particularly of millennials in developing countries, in order to enable them to make best use of the opportunities offered by ICTs;

(d) Collect evidence on how ICTs facilitate collaboration between millennials from developed and developing countries to tackle complex developmental challenges and further undertake research on how best to facilitate such collaboration;

(e) Play an active role in creating awareness about the need to conduct digital ecosystem audits in developing countries and act as a forum to share best practices of digital ecosystem audit methodologies.

50. Member States are encouraged to consider the following suggestions:

(a) Collaborate with all relevant stakeholders, develop regulations and initiate pilot projects that will facilitate the wider application of emerging technologies such as TV white space (momentarily unused spectrum) and next-generation small satellites, giving special attention to their potential to ensure digital inclusion and sustainability;

(b) Bring ICTs to the core of national and international development agendas by recognizing their cross-cutting enabling role in attaining the sustainable development goals;

(c) Conduct audits of national digital ecosystems to identify weaknesses and make effective policy interventions to strengthen the weaker components of the digital ecosystem, while recognizing the interlinkages between its diverse components;

(d) Mobilize and direct financial resources through multiple channels, including crowdfunding and public–private partnerships, to strengthen ICT infrastructure, including human resources capabilities, in developing countries;

(e) Encourage the creation of collaborative structures for digital development policy that will help bring together different stakeholders to create coherent policies to deal effectively with different focus areas of digital policies, such as promoting digital inclusion and digital sustainability, strengthening the digital ecosystem and limiting digital threats;

(f) Use ICTs to create channels that engage millennials in the implementation process of national development agendas and the attainment of the sustainable development goals;

(g) Through appropriate primary, secondary and higher educational and vocational training policies, enhance the digital innovation capabilities of citizens, along with complementary skills such as analytical ability, communication and interpersonal skills;

(h) Encourage a community-based approach to ICT capacity-building, especially by providing platforms for the younger digital natives to share their knowledge of ICTs and train their community in ICT usage;

(i) Take adequate policy interventions and spread awareness to limit threats related to ICT usage such as cybercrime, gambling, pornography, the curtailment of human rights and the creation of monopoly power in ICT services;

(j) Encourage the development of local content on the Internet and other ICT applications as a means to ensure digital inclusion and bridge the content divide;

(k) Collaborate with all relevant stakeholders, promote the application of ICTs in non-ICT sectors to improve environmental sustainability and ensure the creation of suitable facilities to recycle and dispose of e-waste.

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Strategic foresight for the post-2015 development agenda

Report of the Secretary-General

Executive summary

This report identifies, analyses and presents for discussion key issues concerning the role of strategic foresight for policymakers, particularly in developing countries. Chapter II provides an introduction to strategic foresight and its use around the world. Chapter III presents key trends related to science, technology and innovation (STI) that are likely to be relevant for development in the post-2015 period, based on the findings of the meta-analysis of recent foresight reports and inputs from international foresight experts, together with a critical assessment of their potential socioeconomic and development impacts. Chapter IV highlights key policy lessons. Chapter V presents findings and suggestions for consideration by national Governments and other relevant stakeholders.

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Introduction

1. The Commission on Science and Technology for Development (CSTD), at its seventeenth session in May 2014, selected strategic foresight for the post-2015 development agenda as one of two priority themes for the 2014–2015 intersessional period.

2. To contribute to a better understanding of this priority theme and to assist the Commission in its deliberations at its eighteenth session, the CSTD secretariat convened a panel meeting in Geneva, Switzerland, from 26 to 28 November 2014. This report is based on the findings of the intersessional panel, including the expert discussions held during the strategic foresight café organized within the framework of the panel, national reports contributed by members of the Commission and inputs from experts in different regions.

I. Strategic foresight in theory and practice[1]

3. Strategic foresight (also referred to as technology foresight or future-oriented technology analysis) is the systematic assessment of STI in the long term and their potential impacts on society, with a view to identifying areas of scientific research and technological development likely to influence change and produce the greatest societal benefits.

4. As the most upstream element of the technology development process, foresight provides input to technology strategies, policies and plans by proposing pathways to reach a defined vision. Foresight thereby guides the development of technological infrastructure, supports innovation and provides incentives and assistance to enterprises in the domain of technology management and transfer, leading to enhanced competitiveness and growth.

5. Strategic foresight exercises are prepared based on a participatory process that involves structured debate among policymakers, experts, industry and civil society representatives and other stakeholders, leading to a shared understanding of long-term issues. Assessments can be conducted using one or a combination of several methodologies to systematically gather anticipatory intelligence from a wide range of knowledge sources.

A. Common foresight methodologies

6. Various foresight methodologies are used in different countries around the world. The sharing of foresight experiences is part of a research process called mapping, which involves the systematic monitoring and analysis of foresight practices, players and outcomes. Recent foresight mapping work suggests rising interest in strategic foresight, mainly because forward-looking activities have become more than merely tools to support policy or strategy development in STI. The constantly expanding scope of foresight involves a wider range of objectives, including analysing the future potential of STI, promoting network-building, setting priorities for STI, supporting methodology and capacity-building and generating shared visions. In addition, mapping efforts show that multi-scope or multipurpose foresight is now a common phenomenon.

7. The mapping of foresight practices has helped to identify methods that are widely used globally. An examination of close to 1,000 exercises from around the world shows

[1] L Georghiou, JC Harper, M Keenan, I Miles and R Popper, 2008, *The Handbook of Technology Foresight: Concepts and Practice* (Cheltenham, Edward Elgar Publishing).

that the top ten most widely used foresight methods are the following, in order of occurrence: expert panels, scenarios, trend extrapolation, futures workshops, brainstorming, Delphi,[2] interviews, key technologies,[3] questionnaires and/or surveys and strengths, weaknesses, opportunities and threats analyses.[4] Two of the most important factors influencing the selection of methods are their nature (qualitative, quantitative or semi-quantitative) and mix (dependence or influence on other foresight methods). Qualitative approaches are favoured, while some methods are more suited to being used together, such as the frequent use of brainstorming as an input for the Delphi method.

8. Information and communications technologies are increasingly applied to most foresight approaches, especially interaction and evidence-based activities. Many applications are available to support modelling, data mining, scanning, participatory processes and visualization, such as online surveys, big-data analysis, web-based horizon scanning and creativity platforms.

B. Strategic foresight around the world

9. A mapping analysis of the top ten foresight methods per region has revealed regional features, such as the frequent use of the key technologies methodology in Southern Europe and North America.[5] Other regional practices are noted in this section.

Europe

10. Foresight exercises in Europe emphasize both anticipating and collaboratively shaping the future through coordinated governance and decision-making. Foresight is increasingly practised in an institutionalized form and there is growing interest in sharing foresight experiences, for example through the European Foresight Platform and the International Foresight Academy.

11. Some countries, such as France, have a rich history of futures work that stretches back several decades and still influences current practice. Others, for example Ireland and the United Kingdom of Great Britain and Northern Ireland, have a shorter history influenced by technology foresight and sustainable futures traditions. In Eastern Europe, little legacy remains of the communist era tradition of futures thinking in the context of State central planning. Recent work has been heavily influenced by technology foresight practices in Northern and Western Europe. The European Commission and the United Nations Industrial Development Organization have played important roles in this policy tool transfer. Activities in Southern Europe began relatively recently, with over half represented by technology foresight exercises in Spain.

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[2] The Delphi method "entails a group of experts who anonymously reply to questionnaires and subsequently receive feedback in the form of a statistical representation of the group response, after which the process repeats itself. The goal is to reduce the range of responses and arrive at something closer to expert consensus" (Rand Corporation, 2015, Topics: Delphi method, available at http://www.rand.org/topics/delphi-method.html (accessed 13 February 2015)).

[3] This method identifies the most influential technologies over a specific time period, to set research and development priorities.

[4] Analysis undertaken by R Popper on data of the European Foresight Monitoring Network (2005–2009), iKnow (2008–2011) and European Foresight Platform (2009–2012). See http://www.foresight-platform.eu/ and R Popper, 2008, How are foresight methods selected? *Foresight*, 10(6): 62–89.

[5] S Bitar, 2013, *Why and How Latin America Should Think About the Future* (Washington, D.C., Inter-American Dialogue) and M Keenan and R Popper, 2008, Comparing foresight style in six world regions, *Foresight*, 10(6): 16–38.

Latin America

12. Foresight in Latin America has evolved slowly but progressively. Many countries have launched national programmes and projects incorporating concepts and techniques from a wide range of international foresight exercises, mainly from Europe. However, the region has also achieved its own foresight style due to the creative use of limited resources, which has at times resulted in effective innovations in practices and tools, from new management systems and online support tools to new ways of achieving stakeholder commitment. International organizations, such as the Organization of the Andrés Bello Agreement on Educational, Scientific and Cultural Integration, United Nations Economic Commission for Latin America and the Caribbean, United Nations Industrial Development Organization and, more recently, the European Commission, have also played a key role in supporting foresight programmes and capacity-building activities in the region.

North America

13. Many of the most popular foresight methods were developed in the United States of America in the 1950s and 1960s and used extensively in both the public and private sectors. Much foresight activity is conducted at State and federal levels in Canada and the United States. The National Intelligence Council of the United States produces a global trends report to shape strategic conversations within and beyond Government. Sectoral technology road map exercises are particularly popular among United States firms.

Asia

14. Japan pioneered the development of national technology foresight and, since 1970, has used the Delphi method to forecast and shape future technological trajectories. Besides having an influence in Europe, experiences in Japan inspired similar exercises in China and the Republic of Korea and in South-East Asia. In the context of the Asia-Pacific Economic Cooperation forum, the Centre for Technology Foresight was set up in 1998 to conduct region-wide studies and develop capabilities in member countries, work largely influenced by practices in Australia, Japan, North America and Northern and Western Europe.

Africa

15. Most foresight exercises in Africa are sponsored or conducted by international organizations, such as the African Development Bank, European Union, Food and Agriculture Organization of the United Nations, International Food Policy Research Institute, Joint United Nations Programme on HIV/AIDS and United Nations Development Programme. The majority of exercises consider Africa as whole and only a few focus on individual countries.

II. Key trends in science, technology and innovation in relation to the post-2015 development agenda

16. The post-2015 development agenda will embody a universal vision to end poverty and transform the world to better meet human needs and the necessities of economic transformation, while protecting the environment, ensuring peace and realizing human rights. The CSTD has noted that in the global quest to shape this agenda, the important role of STI in realizing development aspirations needs to be strongly articulated.[6]

[6] E/CN.16/2014/2.

17. The CSTD, as the torch-bearer of STI issues in the United Nations system, has stressed the importance of creating STI capabilities, promoting entrepreneurship and strengthening innovation capacities as relevant to fostering inclusive and sustainable development. In the context of its priority theme on strategic foresight, the CSTD secretariat organized a horizon-scanning exercise with input from international foresight experts to identify key STI trends that have the potential to contribute to the post-2015 development agenda and sustainable development goals.[7] These trends were discussed at the 2014–2015 intersessional panel, including expert discussions held during the strategic foresight café, and are encapsulated under the following five areas addressed in this chapter: natural resources, energy, climate change, convergence and urbanization.

A. Technologies related to natural resources

18. Industrial and technological developments, as well as changing consumption patterns associated with growing economies and prosperity, contribute to the increasing demand for both renewable biological resources and non-renewable stocks of minerals, metals and fossil fuels. The world is a closed material system, with finite limits on the amount of resources available. Resources are not scarce in absolute terms, yet they may be unevenly distributed globally, making access uncertain and potentially fostering conflict.

19. Innovation plays a complex role in shaping the demand for and supply of resources. Groundbreaking technologies can create new uses for resources and new ways to locate and exploit deposits, potentially increasing the burden on the environment. But innovation can also enable societies to reduce their use of finite and polluting resources and shift towards more sustainable alternatives. The impact of intensifying global competition for resources will therefore depend greatly on whether technological development can be steered towards establishing more resource-efficient ways of meeting the needs of societies. The following sections consider potential technologies that may be useful in managing food and water resources more efficiently.

1. Food

20. Changing demands and uses for agricultural products are driving subsequent changes in food production. As diets shift from cereals-based towards more protein, fat and sugar-based diets and plant-based energy production increases, a nexus forms between differing interests with regard to quality and quantity increases of food, environmental capacity for agriculture, climate change adaptation, economic accessibility of food and increased vulnerability. The following four key technology trends are considered in the context of ending hunger, achieving food security and increasing agricultural productivity: nanofood; cultured meat and efficient animal production; information and communications technology used in agricultural production; and functional foods.

21. Nanofood applications cover the entire food chain process and can result in decreased inputs and waste, increased productivity in agricultural processes and improved

[7] In coordination with V Carabias-Huetter, Lecturer of Technology Foresight at the Institute of Sustainable Development, Zurich University of Applied Sciences, with input from experts from the International Foresight Academy and the European Commission, including Y Blumer, M Hoppe, H Spiess, D Wemyss and C Zipper from the Zurich University of Applied Sciences, K Haegeman from the Joint Research Centre of the European Commission, R Johnston from the University of Sydney, I Mariani, B Park from the Science and Technology Policy Institute of the Republic of Korea and R Popper from the University of Manchester.

quality and safety of food and water supplies, culminating in higher efficiency in food processing.

22. The increasing demand for meat in developing countries can be met through intensification of production, among other solutions. Intensification includes growth-enhancing technologies that have led to improved efficiency and lower environmental impacts. Vaccines are available for livestock, to protect people and animals from harmful pathogens, but cost-effective production and distribution systems are lacking. Meat alternatives such as in vitro manufacturing of meat products through tissue-engineering technology are also available.

23. Sensors are increasingly used for the real-time tracking of animals, crops and machines. Automation of specific tasks by robots or microrobots improves harvesting, picking, weeding and irrigation. The use of mobile telephones and tablet computers provides farmers, as well as suppliers, retailers and policymakers, access to markets, fertilizer sources and weather reports. The use of mobile technology and other information and communications technology applications can also make a difference in farmers' incomes. Currently available services include market (price) information, local weather forecasts and disease diagnostics. The further penetration of mobile networks (second-generation and also, increasingly, third and fourth-generation technologies) is expected to open new opportunities for supporting rural areas.

24. Functional foods have optimized nutritional aims to supply dietary requirements for improving bodily health, decreasing health risks and even curing diseases. Such foods were first developed in Japan in 1991 for specified health uses and to combat increasing health care costs. They can contribute to improving the quality of life of ageing populations.

25. Food security remains a problem in developing countries, particularly in terms of nutritional quality. Developing countries have high agricultural potential that can only be realized through improvements in efficiency. Step-change improvements in productivity help ensure food security and continuous technological inputs help maintain increases in yields. Nanotechnology applications can also contribute significantly to food security by increasing the competitiveness of food producers and improving their market access. Process improvements in meat production may be efficient enough to cover global demand and may have financial, health, animal welfare and environmental advantages over traditional meat. However, it may take time for societies to become accustomed to alternative meats, particularly due to the perception that the production process is unnatural.

2. Water

26. Some of the most challenging water-related problems that may be addressed by technology are water scarcity, particularly due to groundwater depletion, water quality in developing countries, access to water and sanitation in rural and urban settings and the recycling of materials.[8] Deployment of water supply and sanitation infrastructure in developing countries must be accelerated through innovative options that consume less water, energy or capital. Current technological trends focusing on decentralizing sanitation and wastewater filtration to recover energy and nutrients can help increase access to water and sanitation and also improve water quality. The following are three promising technological developments aimed at improving the management of water resources:

[8] For an in-depth discussion on agricultural water management, see United Nations Conference on Trade and Development (UNCTAD), 2011, *Water for Food: Innovative Water Management Technologies for Food Security and Poverty Alleviation* (New York and Geneva, United Nations publication).

decentralized and sustainable sanitation; energy and nutrient recovery from wastewater; and drinking water and wastewater treatment via membranes and advanced water filtration.

27. New sanitation systems in developing countries address the costs and institutional problems associated with infrastructure expansion and connection to a centralized piped wastewater treatment plant. Sustainable sanitation systems consider the entire service chain, as well as end products, and eliminate pathogens. They often incorporate hand washing or flushing and use new treatment materials and methods such as sand, soil and urine separation, incorporating energy recovery, nutrient reuse and ecological sanitation.

28. The energy and nutrient content of wastewater may be captured and recovered for reuse. Anaerobic digestion processes for wastewater and solids can be used to produce energy, such as a methanol-based biogas. Microbial fuel cells have begun to be used to produce electricity, through the metabolism of microorganisms that treat wastewater. Phosphorus and nitrogen are found in appreciable concentrations in biosolids and urine. Therefore, end products may be composted or phosphorus may be directly recovered, via chemical precipitation, pyrolysis or other means.

29. Separation processes that remove pollution, salts or solids from fresh water or wastewater allow for the safer reuse of water and have the potential to be economically productive, while employing previously unusable sources. Nanotechnology for filtration, membrane filtration and seawater desalination are advancing in technical and economic feasibility. New designs include forward osmosis and high-efficiency energy recovery and the integration of renewable energies such as solar.

30. Long-term durability is expected to be achieved in sanitation by minimizing health risks and environmental impacts, with low upfront costs. Decentralized energy and fertilizer sources can contribute to economic development. However, infrastructure constraints on implementation may arise when new technologies involve the renovation of current sanitation systems. Cheaper, smaller and energy-efficient treatment devices allow access to clean drinking water by a greater population, which improves economic productivity, overall health and environmental quality. Nanofilters are likely to be employed in developing regions of the world to provide potable water by 2020.[9]

B. Sustainable energy systems

31. The energy system consists of three interlinked components. On the demand side there is a need for energy services and specific energy carriers, such as for fuels or electricity. On the supply side there are a variety of potential energy sources, whether fossil fuel-based or renewable. The interface of supply and demand is a complex system of local and global markets, transport infrastructures (including the electricity grid) and institutions (such as transmission system operators), which ensures that energy production matches demand. The energy system therefore requires infrastructure that entails high upfront costs and long life cycles, usually decades, involves a variety of actors and is affected by several non-technical factors such as regulatory constraints and consumer lifestyles.

32. According to the International Energy Agency, global energy demand will grow significantly in the coming decades, mainly in developing countries. Energy demand in developed countries is expected to stabilize in the medium term. A number of technological trends are expected to contribute to cheaper, more sustainable, resilient and integrated energy systems in the next few decades. The overview of technology trends in this section

[9] R Silberglitt, PS Antón, DR Howell and A Wong, 2006, *The Global Technology Revolution 2020, In-depth Analyses* (Santa Monica, Arlington and Pittsburgh, Rand Corporation).

is structured according to the three components of an energy system and highlights the challenge for policymakers, which is to address the growth in global energy demands while simultaneously moving to more sustainable energy systems.

1. Demand for energy

33. Energy efficiency, mainly of industry and transport, is expected to increase gradually, driven by technological developments and cost considerations. Annual incremental energy efficiency investments in transport, buildings and industry is projected to increase by about $336 billion up to 2029, frequently involving the modernization of existing equipment.[10] Such measures might bring a return on investment once the respective amount of energy has been saved. Bioenergy can play a critical role in climate change mitigation, but there are challenges such as the sustainability of practices and the efficiency of bioenergy systems. Energy efficiency improvements are expected to be economically viable in the long term due to budget relief from fossil fuel costs and a reduced need for generation capacities. Meanwhile, in developing countries, population and economic growth may diminish the impact of efficiency improvements and there may be fewer resources available to invest in energy efficiency.

34. In developed countries, where a reliable supply of electricity is widely guaranteed, future increases in demand may be due to the widespread implementation of electric cars (e-mobility) or heat pumps. In developing countries, demand is expected to be driven mainly by more widespread use of information and communications technology, which will enable broader access to markets, communications and information exchanges and new economic potential through service provision, towards increased quality of life. Increased electrification in developing countries and the spread of the use of clean fuels for cooking and heating is expected to yield large health benefits. The transition from the traditional use of biomass and a more efficient combustion of solid fuels will reduce air pollutant emissions such as sulphur dioxide, nitrogen oxide, carbon monoxide and black carbon.

35. Construction standards for buildings in growing urban areas considerably impact energy demand, such as for heating and cooling, and the development of energy infrastructure, such as an electricity grid. Adoption of very low-energy building codes and appliance standards for new buildings is expected to lead to energy cost savings, emission reductions and considerable and diverse side benefits. Residential consumers account for a large share of global energy demand, representing up to 40 per cent of consumption in developing countries.[11] In the next 30 years, urban migration in developing countries is expected to demand high levels of new housing infrastructure, with the associated energy infrastructure. In some developed countries, applied standards have already contributed to a stabilization of, or reduction in, total energy demand for buildings. The European Union has set a target that all new buildings should be nearly zero-energy by 31 December 2020.[12]

2. Supply of energy

36. Extraction of unconventional fossil fuel sources, such as shale gas, oil sands and coal-based natural gas, has dramatically expanded in the past decade. This considerably

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[10] Intergovernmental Panel on Climate Change, 2014, *Climate Change 2014: Mitigation of Climate Change* (Cambridge and New York, Cambridge University Press).

[11] L Pérez-Lombard, J Ortiz and C Pout, 2008, A review on buildings energy consumption information, *Energy and Buildings*, 40(3): 394–398.

[12] European Parliament and the Council of the European Union, 2010, Directive 2010/31 on the energy performance of buildings, 19 May, available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0013:0035:EN:PDF (accessed 13 February 2015).

extends the static lifetime of fossil fuels, i.e. the reserve volume divided by current annual consumption. Unconventional sources became economically interesting as a result of both technological developments (such as horizontal drills, hydraulic fracturing, multilateral wells and microseismic monitors) and higher energy prices. While unconventional source reserves function as a buffer for price increases in fossil fuels, they do so only in the medium to long term, due to the time lag between exploration and production.

37. Renewable energy sources such as the sun and wind are generally carbon neutral and can be implemented in a decentralized manner, rapidly brought online and used to connect regions. However, the impact of such sources in different regions depends on local availability, a key determinant of the costs of generation. Large subsidization efforts have been made to bring renewable energies up to scale, such as direct government subsidies for technology, feed-in-tariffs and external financing, for instance for climate change mitigation. Relatively established renewable energy technologies, such as in biogas, wind and solar energy, are expected to mature further, which will bring down their costs and reduce their implementation risks. Production from these sources is expected to increase considerably in the next decades from the status quo of almost 20 per cent to up to 65 per cent by 2050.[13]

38. Many renewable energy technologies, such as wave, tidal and geothermal energy, biomass and nuclear fusion, have not yet reached widespread industrial commercialization. As subsidies, advantageous economic conditions, consumer acceptance, incremental innovation or technology scaling develop, these technologies may also expand. Energy intensity reductions of about 20 per cent may potentially be realized through innovation.

3. Interface of energy demand and supply

39. New challenges from renewable energy arise where the supply and demand sides of energy meet – i.e. in transport, delivery, storage and consumer services – for instance in large-scale intermittent power generation, which will either require additional reserve capacities or demand-side management measures to ensure adequacy of supply. In addition, new technologies such as affordable solar power panels or (bio)gas-fired microturbines may empower consumers to become prosumers, leading traditional supply chains to resemble networks. One of the biggest challenges in electricity supply, therefore, is managing the grid to accommodate intermittent and decentralized production along with centralized production, as well as flexible prosumers and consumers and storage capacities. The following three technological trends enhance this interface: smart energy systems; the development of energy transport infrastructure; and energy storage.

40. The advancement of information technology services and the mining of big data have led to the personalization of energy use for end customers. Intelligent devices that measure energy use, provide instant feedback, adapt to individual lifestyles and respond to changes in the energy grid all result in demand that is more adaptable to current energy situations and more responsive to energy use. Smart energy systems help consumers become more energy efficient through better information transfers. In addition, the integration of decentralized renewable energy into the grid is possible with relevant grid codes, i.e. operational practices that account for interruptions from generators of renewable energy. Many countries are adapting transmission grids to be able to integrate higher shares of variable renewable power.[14]

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[13] International Energy Agency, 2014, *Energy Technology Perspectives 2014: Harnessing Electricity's Potential* (Paris).

[14] International Renewable Energy Agency, 2014, *REmap 2030: A Renewable Energy Roadmap* (Abu Dhabi).

41. The development of energy transport infrastructure entails high upfront costs and requires long-term financial viability. It is a crucial factor in the integration of renewable sources. In Europe, for example, it requires building a high-voltage electricity grid that is capable of connecting large-scale renewable electricity production sites in the North Sea (offshore wind power) and North Africa (solar thermal power) with demand hotspots (mainly large European cities) in a robust way. In developing countries, the use of decentralized off-grid electricity systems is promising, although they require storage or high flexibility in demand in order to avoid the need for costly transmission systems and to minimize grid power losses over long distances.

42. New energy storage technologies will greatly facilitate renewable energy integration, which may be a necessary flexibility for rural energy provision. In contrast to oil products and natural gas, storage systems will become ever more important for electricity in particular, as it is difficult to stockpile and its production and consumption need to be balanced at all times since there is no buffer in the grid. Storage systems include traditional approaches such as pumped hydropower, but also technological options that are not yet available on a large scale mostly due to cost constraints, such as batteries, supercapacitors or fuel cells that can be powered by hydrogen.

C. Technology for climate change mitigation, adaptation and carbon offset

43. Technology plays an important role in combating climate change and its impacts, as assessed by the Intergovernmental Panel on Climate Change and the Organization for Economic Cooperation and Development, among others.[15] The policy scenarios investigated by the Organization for Economic Cooperation and Development model different technology pathways to reduce emissions and achieve a 450 parts per million emission pathway with the same timing of emission reductions but assuming different patterns of technological development, as follows:

- 450 accelerated action: All technologies available for keeping mitigation costs as low as possible, within boundaries set by capacity constraints
- Low efficiency and renewable sources: Assumes lower efficiency improvements in energy use compared to default assumptions under 450 accelerated action scenario, through lower level of improvement of energy inputs in production and slower increases in production from renewable sources
- Progressive nuclear phase-out: Assumes nuclear capacity currently under construction and planned until 2020 will be built and connected to the grid and that after 2020, no new nuclear units will be built, in order that world total capacity by 2050 will be reduced due to natural retirement of existing plants
- No carbon capture and storage: Assumes no greater use of carbon capture and storage technologies beyond levels projected under 450 accelerated action scenario[16]

44. In the short term, until 2020, altering the set of climate change mitigation technologies results is expected to result in only limited changes in the mix and level of electricity generation. In the longer term, to 2050, the role of renewable energy technologies is expected to be more pronounced, and renewable electricity is projected to supply about half the needs in member countries of the Organization for Economic

[15] Intergovernmental Panel on Climate Change, 2014, and Organization for Economic Cooperation and Development, 2012, *Environmental Outlook to 2050* (Paris).

[16] Organization for Economic Cooperation and Development, 2012.

Cooperation and Development and in China, Brazil, India, Indonesia, the Russian Federation and South Africa, which will also rely on capital-intensive nuclear and fossil-fuel plants with carbon capture and storage. The Organization for Economic Cooperation and Development states that the "results reveal strong complementarities between nuclear and fossil fuels (with or without carbon capture and storage) in most regions".[17] Under the progressive nuclear phase-out scenario, China, Brazil, India, Indonesia, the Russian Federation and South Africa in particular may face a gap in electricity generation.

45. Decarbonizing (i.e. reducing the carbon intensity of) electricity generation is a key component of cost-effective mitigation strategies to achieve low stabilization levels. Mitigation scenarios with policies that stabilize atmospheric concentrations in the range of 430 to 530 parts per million carbon dioxide equivalent by 2100 lead to substantial shifts in annual investment flows during the period 2010–2029 compared to baseline scenarios. During this period, annual investment in conventional fossil-fuel technologies associated with the electricity supply sector is projected to decline by about $30 billion, while annual investment in low-carbon electricity supply (i.e. from renewable sources, nuclear and electricity generation with carbon capture and storage) is projected to rise by about $147 billion.[18]

46. Greenhouse gas emissions from energy supply can be reduced significantly by replacing current coal-fired power plants with modern, highly efficient natural gas combined-cycle power plants or combined heat and power plants, provided that natural gas is available and fugitive emissions associated with extraction and supply are low or mitigated. In mitigation scenarios reaching atmospheric concentrations of about 450 parts per million carbon dioxide equivalent by 2100, power generation from natural gas without carbon capture and storage acts as a bridge technology, with deployment expected to increase before peaking, then falling to below-current levels by 2050 and declining further in the second half of the century.

47. Power plants with carbon capture and storage are expected to become competitive around 2030 and increasingly so by 2050 in member countries of the Organization for Economic Cooperation and Development and in China, Brazil, India, Indonesia, the Russian Federation and South Africa. Under the no carbon capture and storage scenario, switching to alternative technologies, including renewable energy sources, would likely increase electricity prices and alter consumption patterns. Under each scenario, technological and productivity improvements will have a strong impact on the climate change mitigation potential of the energy mix.

D. Converging technologies

48. The history of technological progress provides compelling evidence that change is often not linear but exponential. Dynamics increasingly come from the convergence of technologies.[19] Acceleration in technological change may also lead to breakthroughs that could affect economic sectors that have been slower to change in the past, notably energy and transport. The following sections consider the three convergence areas – biotechnology, nanotechnology and advanced materials and manufacturing – identified by the horizon-scanning exercise organized by the CSTD secretariat as potential game changers in the context of sustainable development goals.

[17] Ibid.
[18] Intergovernmental Panel on Climate Change, 2014.
[19] R Silberglitt, et al., 2006.

1. Biotechnology trends and applications

49. Recent advances in the ability to manipulate and modify living systems have enabled improvements in health monitoring, disease control and therapeutic and prosthetic options and have even given rise to the possibility of designed organisms. Reaction to these developments varies widely throughout the world, with some countries and regions opting for slower development due to ethical issues and concerns about environmental risks and others embarking on a faster development path. By 2020, "the following applications of biotechnology will be technically feasible:

- Performance of many different bioassays on a sample at once, which will enable rapid analyte identification from very small amounts of material, for both medical diagnoses and forensic evaluations
- Personalized medicine, based on large databases of patient information and disease states, as well as the ability for rapid and parallel gene sequencing
- Development of genetically modified insects, such as pests that produce sterile offspring or that do not carry or transmit disease vectors
- Widely available capability for genetically modified staple food crops, with especially strong impact in the developing world
- Ability to design and test new drugs using computer simulations (in silico), as well as new capabilities to test for harmful side effects on model systems assembled on computer chips (lab-on-a-chip)
- Targeted drug delivery to organs or tumours using molecular recognition
- Implants and prostheses that mimic biological functions, restore critical functions to existing organs or tissues, or even augment those functions"[20]

50. Such technological trends are expected to make health care more personalized, predictable, cost-effective and easy to access, including in remote places. While some new technologies may make treatments more complex and expensive, other technologies will make treatments cheaper, more efficient and available for many. Examples of such applications include targeted drug therapies and increasingly accurate diagnostic and surgical methods using biological materials and processes.

51. Funding frameworks based on citizen science, crowdfunding and angel philanthropy are designed to provide for personalized, predictive, preventive and participatory medicine in the developing world. Development aid may focus on supporting such novel frameworks, to help developing countries take full advantage of technological opportunities such as health informatics and to strengthen their biotechnology innovation ecosystems.

2. Nanotechnology trends and applications

52. Nanotechnology, specifically research and development in nanometre-scale science and related technologies, is a burgeoning field worldwide and this "worldwide interest is based on the belief that the ability to understand and affect atomic and molecular interactions at the nanoscale is both a prerequisite and an enabler for a host of technological capabilities, from smart, multifunctional materials to designer drugs and new generations of information and communications systems".[21] The following "applications of nanotechnologies will be feasible by 2020:

[20] Ibid.
[21] Ibid.

- New families of miniaturized, highly sensitive and selective chemical and biological sensors
- Improvements in battery power management and capacity
- Individually worn sensors, especially for military and emergency personnel
- Computational devices embedded in commercial goods (already done today and likely to become more widespread)
- Wearable personal medical monitoring devices with data recording and communications capability
- Functional nanostructures for controlled drug delivery and for improved performance of implants and prosthetic devices
- Capability for widespread human and environmental surveillance and monitoring"[22]

53. Nanotechnology is especially relevant because, given that the properties of materials change with decreasing size, the ability to design and manufacture materials and increasingly complex structures and devices at the atomic or molecular scale offers many approaches and tools that can vastly enhance the ability to detect and remedy environmental deterioration. Examples include nanotechnology for energy conversion and storage, such as dye-sensitized solar power cells. Nanomaterials are also likely to enable the development of functional building materials such as self-healing and self-cleaning concrete.

3. Advanced materials and manufacturing trends and applications

54. The multidisciplinary field of advanced materials has grown over the past few decades through the integration of physics, chemistry, metallurgy, ceramics, polymer science and, most recently, biology, to become a rich source of technological advancement. Advanced materials are enablers of many of the applications of biotechnology and nanotechnology. Based on continued developments in materials science and engineering and manufacturing, the "following may be feasible by 2020:

- Fabrics that incorporate power sources, electronics, and optical fibres
- Clothes that respond to external stimuli, such as temperature changes or the presence of specific substances
- On-demand manufacturing of components and small products to individual personal or corporate specifications (initially limited to low-complexity items)
- Widespread adoption of green manufacturing methods that substantially reduce the introduction of hazardous materials into commerce and the volume of hazardous waste streams
- Nanostructured coatings and composite materials with greatly enhanced strength, toughness, wear resistance and corrosion resistance
- Organic electronics for increased brightness of lighting systems and displays
- Mass-producible solar cells using composite materials based in part on nanostructured, organic or biomimetic materials
- Water purification and decontamination systems based on nanostructured, activated membranes and filters

[22] Ibid.

- Designed catalysts for chemical processes based on combined rapid computation and materials screening
- Engineered multifunctional tissues grown in vivo from biodegradable scaffolds (likely limited initially to selected tissue and organ types)"[23]

55. Advances in materials science are often followed by product innovations. In the coming years, disruptive technologies are expected in the area of nanomaterials (such as graphene, carbon nanotubes and nanoparticles), photonics and three-dimensional circuits, universal memory and multicore, which are the foundations for running information and communications technology products and processes.

56. Constant adaptability is expected to pervade all aspects of manufacturing, from research and development to innovation, production processes, supplier and customer interdependencies and lifetime product maintenance and repair. Products and processes will be sustainable, with built-in reuse, remanufacturing and recycling for products reaching the ends of their useful lives. Closed-loop systems will be used to eliminate energy and water waste and to recycle physical waste. Advances in materials science, microelectronics and information technology, biotechnology and nanotechnology will profoundly affect manufacturing and help manufacturers address the challenges to come.

57. By 2020, green manufacturing techniques are likely to provide a variety of more environmentally friendly alternatives to manufacturing processes that currently use or produce hazardous materials. Using such techniques, manufacturers are expected to be able to sustain levels of production in stricter regulatory environments while consuming fewer non-renewable resources, creating less hazardous waste streams and reducing their impacts on the environment. Additive manufacturing (three-dimensional printing) will help reduce the time-consuming long-distance transport of products or components that are currently mass produced and may shift industrial production from peri-urban areas to city centres.

58. It is important to note that advanced materials and manufacturing technologies are in the early stages. Their long-term impact, particularly in terms of value chains, represents a research area that has yet to be explored.

E. Urbanization and habitat[24]

59. Cities are places of markets and innovation. They are at the forefront of economic wealth creation, as most innovation and paid employment tends to be located in urban areas. Urbanization is therefore a driver of economic development not only for cities but for their surrounding regions or countries. Economic growth in cities and improvements in infrastructure have been shown to intensify urban migration. In addition, cities are a prime example of sociotechnical systems where technical and socioeconomic developments co-evolve. For example, urbanization is strongly interlinked with mobility, the use of natural resources and energy. This section provides insights as to how emerging technologies interact with such developments.

60. According to the United Nations Department of Economic and Social Affairs, by the year 2050, the global share of people living in urban areas will increase to approximately 66 per cent, led by cities in Asia, Latin America and, particularly, Africa.[25] In many regions, medium-sized cities are expected to grow faster than megacities with over

[23] Ibid.

[24] For an in-depth discussion on this topic, see E/CN.16/2013/2.

[25] United Nations Department of Economic and Social Affairs, 2014, *World Urbanization Prospects* (New York, United Nations publication).

10 million inhabitants. One strong trend is the extension of city areas; efforts to promote a reurbanization of the city core, also known as densification or compact cities, are unlikely to compensate for the trend towards sub and peri-urbanization, although large-scale effects may be achieved by building infrastructure in compact urban areas for various services such as housing, sanitation, health care or access to electricity.

61. Supplying urban areas with goods and resources is becoming ever more complex. While previously, most food and other consumer goods for a city were produced in its urban hinterland, large cities today are embedded in international trade networks. While the dependence of urban areas on surrounding rural areas is therefore decreasing, their dependence on global markets is increasing.

62. Urbanization can benefit from technological trends in the following three areas: information and communications technology; vehicle and engine technologies, materials, infrastructure and operating technologies; and technologies for self-sufficiency.

63. City authorities are expected to have access to ever more sophisticated information and communications technology tools (such as geographical information systems) to manage and visualize large amounts of real-time or near-real-time data relevant to city development, collected with the help of sensors, satellites and mobile crowdsourcing, among others. Such technology will also optimize transportation systems through mass-mobility applications, including traffic-flow control and fleet management, and its use in intelligent vehicle technologies. In public transportation, electronic ticketing and payment will improve services, leading to a higher degree of capacity utilization. Finally, smart travel cards, services and applications are expected to combine different public and private services, such as private car-sharing initiatives, leading to seamless mobility.

64. Vehicle and engine technologies are expected to lead to improvements in transportation and mobility, including high-speed trains and autonomous vehicles, electric, hybrid and fuel-efficient vehicles, lightweight material technologies, nanosolutions for batteries or engines and technologies enabling the reduction of physical mobility, such as for communications or virtualization, or even three-dimensional printing.

65. Urban agriculture, partly based on biotechnology or organized in multi-storey platforms through the use of construction and building technologies, can reduce the inflow of food from rural areas and increase the self-sufficiency of urban populations. Emerging technologies such as for solar or wind energy may reduce the dependence of cities on surrounding rural areas for energy supply by enabling energy production inside urban areas. In addition, improved thermal insulation of buildings reduces the need for fossil fuels.

III. Policy lessons learned from horizon-scanning exercise and foresight research

66. The horizon-scanning exercise organized by the CSTD secretariat and foresight research conducted for this report identified a range of technology trends that may have the potential to contribute to development, particularly in the context of the post-2015 development agenda. Four policy lessons can be identified, and are detailed in this chapter.

1. The selection of technological paths depends on the context of countries

67. Not all countries are faced with identical challenges; each is at a different stage of development, with different technological capabilities, cultures and priorities. In addition, it is necessary to consider that wide differences exist between implementation capacity, investment costs and the long-term impact of each technology. Policymakers are confronted with questions of context and relevance when evaluating technologies, and selection should

be based on the specific socioeconomic needs and cultural context of countries, especially given that some technologies could facilitate progress towards multiple sustainable development goals.

2. Technology trends cannot produce positive development outcomes on their own

68. Technological development does not ensure development outcomes. For example, convergence spurred by information and communications technology and electrification has the potential to provide solutions in the areas of agriculture, health care and good governance. However, such technological solutions do not necessarily imply that social inequalities have been overcome and in some cases may result in higher inequality. Policy intervention is therefore needed to prevent the creation of new inequalities or the amplification of existing ones.

69. Policies need to address infrastructure gaps, particularly in the underlying requirements of new technologies such as access to electricity and information and communications technology, and encourage transdisciplinary and interdisciplinary research based on the findings of technology foresight studies. Special attention should also be paid to the creation of capabilities, as countries need to have the capabilities to identify and derive the benefits of advances in science and technological applications. In addition, technologies need to be complemented by behavioural changes and incentives, in order to have a significant impact. Monetary and non-monetary incentives, as well as information measures, may facilitate behavioural changes. For example, emissions can be substantially lowered through changes in consumption patterns, dietary changes and reductions of food wastes.

3. The role of converging technologies is increasing

70. Analysis of technology trends provides evidence of the increasing role of converging technologies, as discussed in chapter II. Information and communications technologies are key drivers of such convergence and are increasingly present in various socioeconomic areas, including food production, mobility, urbanization, energy supply and health. A more widespread use of information and communications technology may be applied to a variety of issues, ranging from farming to energy supply and urbanization. This is an area that deserves policy attention.

4. Collaboration can contribute to advancing technology foresight in developing countries

71. Regional and international collaboration plays an important role in advancing technology foresight in developing countries. It is beneficial for countries in the same region to use existing regional institutional platforms, pool available resources and maximize impact through joint foresight exercises to address common challenges. Countries that are not in the same region but face similar development challenges, for example, landlocked developing countries, least developed countries and small island developing States, may also consider joint foresight initiatives. It is important to foster the exchange of experiences among developing countries and countries that have been successful in overcoming similar challenges in the past.

IV. Findings and suggestions

72. This chapter proposes a set of key issues for consideration by the Commission, drawing on the findings of the 2014–2015 intersessional panel, including the expert discussions held during the strategic foresight café, and the horizon-scanning exercise.

1. Findings

73. The findings of the panel were as follows:

(a) Strategic foresight has evolved in the last decades into a participatory process that is increasingly employed by countries and regions to gather intelligence on future trends so as to allocate resources in a way that prepares societies for such trends. Various methodologies and institutional arrangements are used, depending on the specific objectives of a foresight exercise.

(b) Several emerging technology trends have been identified as having a major impact on the post-2015 development agenda, including in the areas of natural resources, sustainable energy, climate change mitigation, adaptation and carbon offset, converging technologies, health and disaster resilience, urbanization and habitat and sustainable transportation and mobility. These trends do not automatically produce societal benefits and policy intervention is needed to prevent the creation of new inequalities.

(c) Technology convergence, which is predominantly driven and facilitated by information and communications technology, necessitates transdisciplinary and interdisciplinary approaches, when responding to complex societal challenges by using STI.

(d) Technology foresight can help policymakers better understand unsustainable trends and contribute to the implementation of the post-2015 development agenda by informing it on a regular basis. Technology trends should be analysed in the context of wider socioeconomic trends, to identify their societal impact.

(e) Technology foresight can help anticipate future innovation policy and private sector investment needs, particularly with regard to critical infrastructure needed for sustainable development and attaining sustainable development goals. Foresight generates insights on the dynamics of change, future challenges and options and new ideas, to transmit them to policymakers as inputs for policy design.

(f) Foresight is increasingly becoming an essential multi-stakeholder tool to make sense of and create strategic options to deal with today's complex global challenges, which are difficult to define, require new ways of thinking, lack clear accountability, transcend national boundaries and require a long-term approach.

(g) Vocational training can provide a major boost in terms of preparing the workforce for disruptive technologies. Appropriate strategies may be devised for both preemployment and on-the-job vocational training. Partnerships between universities, non-governmental organizations and the private sector are indispensable for the success of vocational training on a significant scale.

2. Suggestions

74. The CSTD may wish to consider the following:

(a) Sharing findings on STI and information and communications technology trends and their implications in the High-level Political Forum on Sustainable Development, the Global Sustainable Development Report and in sustainable development goals implementation processes.

(b) Establishing a knowledge portal to share peer-reviewed foresight practices conducted at national and regional levels, thereby assisting member States in identifying future trends and potential strategic partnerships.

(c) Contributing to capacity-building, awareness creation and impact assessment for foresight initiatives in member States.

(d) Encouraging the Science, Technology and Innovation Policy Reviews of UNCTAD to focus more on strategic foresight, possibly by including a dedicated chapter on this theme.

75. Member States may wish to consider the following:

(a) Fully integrating STI into national socioeconomic development plans and ensuring that STI objectives are driven by societal needs, as opposed to analysing STI trends in an isolated way.

(b) Using strategic foresight to identify potential gaps in education for the medium and long term and addressing such gaps with a policy mix including, among others, vocational training, counselling, open access provision and quotas and targets to encourage enrolment in science, technology, engineering and mathematics.

(c) Strengthening vocational education to prepare societies for disruptive technologies by establishing dedicated national vocational training institutions, increasing cooperation between vocational training institutions and industry and funding training facilities, student exchange programmes and equipment.

(d) Using foresight as a process to encourage structured debate among all stakeholders, including representatives of Government, science, industry and civil society and the private sector (particularly small and medium-sized enterprises), towards a shared understanding of long-term issues and building consensus on future policies.

(e) Undertaking strategic foresight initiatives on global and regional challenges at regular intervals.

(f) Using existing regional mechanisms to kick-start cooperation on foresight studies, particularly to learn from countries that have overcome development challenges by using STI and information and communications technology, and to jointly tackle common challenges.

(g) Cooperating towards the establishment of a mapping system to share technology foresight outcomes with other member States of the CSTD.